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Some Thoughts on Molecular Physiology.

AN

INTRODUCTORY LECTURE,

DELIVERED WEDNESDAY, 28TH OCTOBER, 1885,

BY

JOHN GRAY M'KENDRICK, M.D.,

LL.D., F.R.SS.L. & E., F.R.C.P.E.,

PROFESSOR OF PHYSIOLOGY IN THE UNIVERSITY OF GLASGOW.

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Some of the thoughts in this Lecture were suggested by the article "Physiology," in the *Encyclopædia Britannica*, by Professor MICHAEL FOSTER, a masterly contribution to the Philosophy of Physiology.

J. G. M.

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GLASGOW VETERINARY COLLEGE.

The Winter Session of this Institution began on Wednesday, 28th October, when the Introductory Address to the students was delivered by Dr. M'Kendrick, Glasgow University. The proceedings took place, as usual, in the Lecture Hall of the College, at 83 and 85 Buccleuch Street, and there was a large attendance. Principal M'Call occupied the chair; and, in introducing the Lecturer, intimated letters of apology from Francis W. Clark, Esq., LL.D., Sheriff-Principal of Lanarkshire; Principal Robertson, London Veterinary College; and Professor Ferguson, Dublin, etc., etc. In addition to a large number of students, the following gentlemen among others were present:—Rev. Mr. Scott, Bargeddie; Rev. Mr. Ramsey, Baillieston; Dr. Marwick, City Chambers; Captain M'Call; D. Forsyth, Esq., M.A., B.Sc., Church of Scotland Training College; James Cuthbert, Esq.; Mr. Brand, Baillieston; and Mr. Young, Easterhouse; Professors Cook, Limont, Macqueen, and Renfrew, Glasgow Veterinary College. The following veterinary surgeons were also present:—Mr. Kernohan, Ballymena; Mr. Peddie, Cathcart; Mr. M'Dougall, Oban; Mr. Douglas, Kilmarnock; Mr. Hamilton, Hamilton; Mr. Kerr, Dalry; Mr. Green, Irvine; Mr. Nisbet, Galston; Mr. Gardner, Helensburgh; Mr. Macgregor, Dunbarton; Mr. M'Nair, Saline, Fifeshire; Mr. Wilson, Nantwich; Mr. Dobie, Birkenhead; Mr. Campbell, Kirkcudbright; Mr. Allen, Clarkston; Mr. Bond, Holytown; Mr. Brown, Holytown; Mr. Brownlie, Coatbridge; Mr. M'Call, Ayr; Mr. Taylor, Rutherglen; Mr. Reid, Kirkintilloch; Mr. Gray, Lochgilphead; Mr. M'Farlane, Greenock; Mr. Constable, Inchture; Mr. Galloway, Perth; Mr. Spalding, Blairgowrie; Mr. Mackeand, Dalbeattie; Mr. Leckie, Dumfries; Mr. M'Ilwraith, Milngavie; Mr. Ferguson, Greenock; and Messrs. Brock, Anderson, Frew, M'Lean, Robb, Wallace, Weir, Wyper, Forbes, Tweedley, and Blue, Glasgow.

INTRODUCTORY.

Gentlemen,—I had great pleasure in acceding to the request of your Principal to deliver an address at the opening of the session, because circumstances have led me to take a deep interest in veterinary science, and I am to some extent familiar with the course of study followed by veterinary students. About ten years ago I held the office of Lecturer on Physiology in the Dick Veterinary College in

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Edinburgh, and I always look back on my connection with that college with feelings of gratitude, because the studies requisite for the position led me to take a broader view of physiology than I would probably have done had my experience as a teacher been confined entirely to students in our medical schools. My connection with the Dick College was also the channel by which I became connected with an important trust. The late Miss Dick, sister of Professor Dick,—a man of indomitable energy and of great power, and the founder of the college in Edinburgh,—appointed Professor Turner, Professor Chiene, Mr. Middleton Rettie, Advocate, and myself her trustees. The Trustees are directed to allow the funds left by Miss Dick to accumulate until they reach a certain amount, when they are to be divided into two equal parts, one part, £10,000, to be devoted to the furtherance of veterinary science in Scotland by aiding the Dick Veterinary College, and the other part, £10,000, to be used for founding in the University of Edinburgh a chair of Comparative Anatomy, or of Surgical Anatomy. The money is steadily accumulating; and when the provisions of the Trust are carried into effect, they cannot fail in having a most important influence on the progress of veterinary science, and also on the progress of Anatomical science generally.

I have now, in the name of the Principal and Professors of this College, to give you a warm welcome, and to express the hope that you will enter on your duties with earnestness of purpose. You have chosen a highly useful profession, and in preparing yourselves for it you will pass through a course of study which is full of interest, whilst it is also a healthy mental discipline, calculated to develope many of the best parts of a man's nature. You will get a glimpse into the world of science; the chemist will teach you not a little regarding the chemical and physical laws that regulate everyday phenomena, and regarding the properties of the matter of which this universe is built; the botanist will lay before you many of the wonderful processes of plant life, and will awaken your interest in the flowers of the field; whilst the anatomist and physiologist will discuss with you the still more remarkable processes going on in the animal body—processes, a knowledge of which not only involves the highest problems of physical and chemical science, but lies at the root of some of the most profound questions in philosophy. Your scientific training, therefore, apart altogether from the study of the more technical branches of your profession—such as veterinary medicine and surgery—is fitted to extend your mental vision, to enlarge your ideas, to awaken thought, and to stimulate enquiry; and I confess I do not envy the man who can pass unmoved through such a course of study. To appreciate it, however, let me advise you to enter on it with some enthusiasm. Do not think of science as a barren collection of facts, or as a certain amount of knowledge that must be acquired so as to aid you in the more practical studies. It is all this, but it is much more: it is a privilege granted to man to see into some of the wonderful processes of the universe.

Cultivate a habit of reverentially looking at these things; view them as the devout theologian regards the solemn truths of his science; ever remember that behind all the facts and phenomena known to man there are many more of which he knows little or nothing. Such a frame of mind, whilst it enables a man thoroughly to enjoy the study of natural phenomena, will save him from the conceit and rash dogmatism which have not unfrequently brought opprobrium on science and on its followers.

When you pass to the study of the diseases of animals and the means of remedying them, you enter on a field that is most closely connected with the domain of human medicine and surgery. I do not require to enlarge on the usefulness of the veterinary profession. It has the charge of the health and well-being of many millions of animals, which constitute a large portion of the wealth of the nation. It is called upon not only to treat the diseases to which they are liable, but also to ascertain the cause of all disease, more especially of those epidemics which ravage our flocks and herds. It thus includes both veterinary medicine and surgery, and the hygiene of the domestic animals. It deals not only with the cause and consequences of disease but also with its prevention. Disease amongst our domestic animals always represents a certain pecuniary loss. This loss has to be borne, not only by the rich, but also by the poor. For example, any disease which either lessens the number or depreciates the quality of those animals furnishing food to the community, increases the price of meat, and consequently puts it out of the power of many to obtain it. The value of the live stock of this country is enormous, and constitutes a considerable portion of the wealth of the nation. It therefore becomes a matter of the greatest importance to every member of the community, that Veterinary surgeons, who are the advisers of the public in these matters, should be thoroughly educated and prepared for their work. In addition to these considerations, there is also the duty we owe to all animals of promoting their health and wellbeing and of relieving them of suffering and pain.

To meet these demands, the veterinary practitioner should receive the same careful education as those who engage in the treatment of disease in the living man. There is a popular idea that the Veterinary surgeon does not require to be so well informed as he who deals with the ailments of man. This idea no doubt arises from the higher value justly attached to human life. But if we attempt to treat disease at all, the kind of work to be done in both departments of practice is essentially of the same nature. The structure and functions of the bodies of domestic animals are much the same as in the human being. The diseases to which both are liable present remarkable similarities. The medicines which are found to be useful in the one usually produce beneficial effects in the other. It may be asserted also that the diagnosis and treatment of diseases in the common animals are even a more difficult accomplishment than the same kind of work in man, inasmuch as the patients of the veterinary practitioner can give no direct information regarding their feelings. In this respect practice among the domestic animals resembles the treatment of children, who cannot tell the physician how they feel, nor assist him much in detecting the disease from which they suffer. In treating the dumb animal, the practitioner must therefore depend on objective symptoms. He must have cultivated the practice of rapid and accurate observation. He must collect his information by a careful physical examination of the parts supposed to be the seat of the disease; and he must call to his aid all the appliances and instruments—such as the stethoscope, microscope, and thermometer —which are now used in modern medicine.

Consideration of those facts will at once show the necessity of having our Veterinary practitioners thoroughly educated men. They ought to be conversant, equally with students of medicine, with those sciences on which the art of medicine is founded; and they ought to have equally good opportunities of acquiring a practical knowledge of the profession. This ideal is arrived at in the institution to which you have come. I have looked over the curriculum of study of this college, and its fulness and thoroughness have struck me as remarkable. All I shall say of it is that you must work hard to get through it successfully; it will tax your energies, and try your mental powers; but I have no hesitation in saying that if you pass through it successfully, you will start in your profession with a large stock of theoretical and practical knowledge and be ready for your work.

MOLECULAR PHYSIOLOGY.

The subject in your curriculum which naturally attracts my attention most is Physiology, and perhaps you will permit me to refer to it with some degree of fulness, and thus, in discussing one topic, follow the example of those who have delivered opening addresses in this place in former years. In tracing the history of any science one soon discovers that there are times when, in consequence of a great discovery, or of a wide generalization, it is necessary to recast the whole subject, or at all events to view it from a new standpoint. The introduction of the atomic theory into chemistry, the recognition of the great law of conservation of energy in physics, and the adoption of a theory of evolution in biology in its various departments, are examples of such epoch-making events. Again, a science occasionally makes a new start. She leaves the old and well-gleaned fields and explores new territories, adding to her stores at every footstep. Such happened in chemistry when the investigator first went into the domain of organic compounds, in physics when, as we have seen even in our own day, the field of electricity has been traversed by a thousand workers, and in biology when the naturalist turned his attention to the study of development or embryology. Some such change is about to happen, I believe, in physiology; at all events so many new facts have been collected in recent years, by the experimental mode of enquiry, as to make it necessary to review the whole ground and to recast some of our older notions. Let me illustrate what I mean.

Physiology, as you know, is intimately connected with anatomy, and most people would at once say that anatomy was the older science. This is true in one sense but not in another, as it is evident that men, in long bygone ages, must first have watched the movements of animals, the taking of their food, and other processes before they began to dissect. They took the body of the animal to pieces to see how it worked. Thus anatomy arose, and its study is justly regarded as preparatory to understanding all vital actions. In later times, anatomists have devoted more and more attention to the study of form and structure, apart altogether from a consideration of the processes by which these forms have been evolved. This department of science is now called morphology, and as Professor Foster has well said, "Were the whole world suddenly petrified, or "were a spell to come over it like that imagined by Tennyson in "his 'Day Dream,' but more intense, so that not only the gross "visible movements but the inner invisible movements which are at "the bottom of growth were all stayed, the morphologist would "still find ample exercise for his mind in investigating the form "and structure of the things which had been alive, and which still "differed from other things in their outward lineaments and internal "build."—*Encyclop. Britann., 9th ed., art. Physiology.*

Physiology now deals with the actions of living beings on their surroundings and with the actions of their surroundings on living beings, and it considers structure only so far as it illustrates or explains action. The progress of the science has shown, however, that there are numerous problems on which a knowledge of structure throws no light. Thus the movements of the body are effected by muscles, and we study anatomically the framework of bones, the joints, the arrangement of the tendons, and their attachment to the bones, and we obtain, by a study of these mechanical arrangements, an idea of how any particular movement is accomplished. But the fact remains unexplained that the movement is effected by a contraction of the muscular fibres by which their ends are approximated, and we are obliged to ask the question, Why do the muscles contract? We find that muscular matter will contract on direct irritation, but that the usual kind of stimulus causing it to contract is some kind of change passing to the muscle along the nerves. This leads us to investigate the actions of the nerves, and we ascertain that the change coming along the nerve to a muscle, which causes it to contract, originates somewhere in a brain or spinal cord, or nerve centre as it is termed; further, we find that the change in the nerve centre may in turn be excited by influences coming to it from the periphery of the body along so-called sensory nerves, and that these influences may, by acting on the nerve centre, originate muscular movements at once, or these may be long delayed. Then, again, we arrive at a knowledge of the fact that many of the changes in these nerve centres are connected with consciousness, and that we must conceive a nerve-centre as frequently in a state of extreme molecular agitation or change, currents flowing in or passing out, connecting the sensory surfaces with the muscular and other apparatuses, and welding the whole body into one harmoniously working machine.

In the next place, we find that food and air are necessary to a living being. The body of a living being is composed of complicated and unstable chemical substances, capable of being oxidised, and of being reduced by oxidation to simpler and more stable compounds, with a setting free of energy. These more stable compounds are water, carbonic acid, some nitrogenous compounds such as urea, and salts. Such substances are produced from organic matter whether it be quickly oxidised by burning, or more slowly in the animal body, or still more slowly in the changes that occur when a body is allowed to decay in the earth. During life, these simple compounds are being constantly produced by oxidation processes, and thus "the animal body dies daily in the sense that at every moment some part of its substance is suffering decay, is undergoing combustion; at every moment complex substances full of latent energy are by processes of oxidation reduced to simpler substances devoid of energy, or containing only a little." Thus we arrive at the astonishing conclusion that "every act of life is the outcome of an act of death." Every contraction of a muscle, every beat of the heart, every action of the nervous system, every formation of something in the cell of a gland, are connected with the splitting up of complex molecules into simpler compounds, or, in other words, with the crumbling down, in a molecular sense, of the tissue. All the energy thus liberated ultimately is set free either as heat or motion in the form of muscular work. Thus energy is being continually expended, and to make up for this we take food which is a mixture of highly complex energy-stored bodies, and we breathe in oxygen whereby the oxidisable matters are reduced to simpler compounds, and the potential energy thus set free does work. But the food is not oxidised simply in passing *through* the body; the compounds formed from it become, for a time, part of the living matter itself.

Thus we see that the ultimate problems of the physiology of the present day are concerned with the changes in living matter on which the phenomena of life depend. This is the characteristic of the science as it at present stands. The first physiologists attempted to explain the phenomena of the body by assuming the existence of animal and vital spirits. The animal spirits were more closely connected with the phenomena of animal life, whilst the vital spirits were common both to animals and plants. By-and-bye it was found that many phenomena could be accounted for without such agencies. The next great step was the recognition of the uses of organs of the body, and the body was conceived to be built up of a series of machines, all more or less independent, and still all co-operating in the general life. The work done by an organ was termed its function. The value of this line of thought was so great that it soon dominated physiology, and in the minds of many it still reigns supreme. Further, it must be pointed out that this view of organs and functions has produced brilliant results in physiology. Thus the doctrines of the circulation of the blood established by Harvey are the outcome of a study of the mechanism of the heart and blood vessels, considered as organs, and many other problems, such as the movements of respiration, the mechanism of voice, etc., are capable of solution by the application of mechanical principles to anatomical facts. The anatomical mode of inquiry, however, did not solve the whole question. Thus when applied to the case of the liver it showed only the arrangement by which blood was carried to and from that organ, and the ducts for carrying away the bile. The function of the liver was therefore said to be to secrete bile, and for many years this was considered to be the only function of that important gland. Another example of the failure of the anatomical method alone is that for many years no function whatever could be assigned to certain organs, such as the spleen, a large and complicated structure, existing apparently without a purpose.

The next great conception that harmonized with and was the completement of the doctrine of organs and functions was the cell-theory which defined the cell as the physiological unit, and all functions of an organ were explained as being the aggregate of the functions of the individual cells forming the organ. It was hoped that by a study of the arrangements of cells, their forms, sizes, and general properties, a knowledge of functions would be obtained.

The purely anatomical mode of enquiry received its first shock by the discovery, about the middle of this century, by Claude Bernard, of the glycogenic function of the liver. He showed that the secretion of bile was not the only function of the liver, but that it formed a large quantity of starchy matter, to which the name of glycogen was given. This discovery could not have been made by the most diligent scrutiny of the cells of the liver with the highest microscopic powers, and a mere knowledge of the arrangements of the gland as regards blood vessels, ducts, and cells would have left this function unknown; while the discovery might have been made by one having no knowledge of the anatomical structure of the liver.

As science advanced, the definition of a cell laid down by the founders of the cell theory had to be modified. The original definition of a cell was a small body having a cell wall, cell contents, and a nucleus or kernel, and it was assumed that here we had the fundamental structure with which the phenomena of life were associated. But discovery showed that these phenomena might be manifested by a mass of matter destitute both of cell wall and of nucleus, and consisting only of a little mass of jelly-like matter, containing a few granules. Then arose the theory of protoplasm. The matter called protoplasm was now regarded as the material basis of life, and the great step was taken of throwing overboard all conceptions of life as the outcome of organization, and the mechanical result of structural conditions. This is the view of physiological processes now generally held. It aims, as has been said, at putting "physiology on the same footing as "physics and chemistry, and regards all vital phenomena as the "complex products of certain fundamental properties exhibited by "matter, which, either from its intrinsic nature, or from its existing "nature, or from its existing in peculiar conditions, is known as "living matter;—mechanical contrivances in the form of organs "serving only to modify in special ways the result of the exercise of "those fundamental activities, and in no sense determining their "initial development." (Foster *op. cit.*)

Further research, however, has shown that there are various kinds of protoplasm, and that even protoplasm, when examined by special methods, affords indications of structure. It is not a homogeneous jelly, nor even a granular jelly, as has been described, but it contains a fibrillar net-work, in the meshes of which there is some kind of matter. It is not, however, strictly correct to speak of this fibrillated arrangement as indicative of structure, or at all events of a permanent type of structure—because it is not constant. It varies much from time to time even in the same mass of protoplasm. This amorphous matter, as found in the amœba, is capable of manifesting the phenomena of life; and in the white blood corpuscles it moves; it assimilates dead food and raises it to the level of living matter; it is the seat of chemical changes of a very active character, and in particular it has powerful reducing properties. It has been shown that the protoplasm of vegetable cells has the power of reducing salts of silver, and on this chemical phenomena Loew and Bokorny have advanced the view that living protoplasm contains a chemical compound of the nature of an aldehyde. Its characteristic condition is one of incessant change; molecular processes are constantly going on in it, leading to the upbuilding or the downfalling of its substance. Whether it be a single highly complex chemical substance, or a number of such substances, we do not know; but even if we suppose it to be one substance, it probably does not exist for more than a very brief space of time in the same condition. At one instant it is made, and in the next it is unmade. It is built up of matter that was once dead but now is alive. Dead food probably rises by a series of steps to the condition of living matter; this living matter is protoplasm; and then the descent on the other side begins, which ends in the matter being split up into the comparatively simple substances which are what we may term the waste products. As Foster puts it:—
"Further, the dead food, itself fairly but far from wholly stable in character, becomes more and more unstable as it rises into the complex living material. It becomes more explosive, and when it reaches the summit its equilibrium is overthrown, and it actually explodes. The whole downward stair of events seems in fact to be a series of explosions, by means of which the energy latent in the dead food, and augmented by the touches through which the dead food becomes living protoplasm, is set free. Some of this freed energy is used up

again within the material itself in order to carry on this same vivication of dead food; the rest leaves the body as heat or motion." (Foster *op. cit.*)

The fundamental properties of protoplasm then are (1) *assimilation*, or the power of converting dead food into its living self; (2) *movement*, or change of form,—*contractility*, as it is usually called,—arising from internal disruptive or explosive changes (using the term "explosive" in the molecular sense); and (3) *irritability*, or the property of responding to stimulation by changes so minute as entirely to escape the observation of the unaided senses. But these fundamental characteristics are manifested in different degrees by different specimens of protoplasm, and even by the same protoplasm at different periods of its life. Thus the changes occurring in one kind of protoplasm may be such that the decompositions result in energy being set free only in the form of heat, no visible changes of form ensuing. This is the case with the protoplasm of the nervous tissues and secreting cells. Again, in another specimen of protoplasm, such as exists in the muscular and other contractile tissues, the energy may be set free both as motion and heat, and the most striking characteristic of the molecular change is movement. It is the business of the physiology of the future to determine what it is that causes one kind of protoplasm to differ from another. If it depended on internal structure, that must be of a molecular character, which no scrutiny with the highest microscopical power can ever detect, as the optical method of inquiry has probably come near its limits. It is true that, as the protoplasm manifests more and more one or other of its fundamental properties, features of a structural character may gradually make their appearance, but even these seem to be of a subsidiary character, and not to be the real cause of the specific kind of action. Thus contractile tissue may, by long-repeated activity and specialization of function, take on the structural characters of striated muscular fibre but these characters are not essential to the contraction of the fibre. Many fibres contract that are destitute of the structural characteristics of striated muscle. Nor is even the existence of matter in the form of a fibre necessary to contraction. The fibre contracts because it contains protoplasm having the fundamental property of changing its form, owing to molecular changes excited by a stimulus. Thus we gain the position now reached by some of the most profound thinkers in physiology, that protoplasm exists in differentiated varieties, whilst each variety still retains more or less of the general properties of protoplasm. In other words, whilst there is variety in the results of protoplasmic life, there are underlying in all the kinds of protoplasm the fundamental characteristics of the primitive substance.

I might illustrate this by tracing the differentiation of the protoplasm of the cells forming the primitive layers of the embryo, showing how the various tissues are built up, and from these the mechanisms we call organs, and pointing out especially that the functions of all these organs depend on the activities of the protoplasm contained in them. Hitherto the attention of physiologists has been largely occupied, and very properly occupied, with investigating the general mechanism of these organs. For example, we are now acquainted with the arrangements of the circulation of the blood, viewing the heart as a contractile force-pump driving the blood through a series of elastic and contractile tubes and guided by valvular structures. There is probably not much to be done in this direction. But there still remains the problem of the molecular changes happening in the wall of the heart itself. What is the cause of its rhythm? What relation has its rhythm to the activity of the clusters of nerve cells in the wall of the heart itself? Again, we know that the blood is driven through the tissues and organs, and that each element of living tissue selects from it the matters it needs for its growth and activity, but there are many occult molecular processes happening in the structures separating the blood from the tissues and in the absorption by the tissues of the nutrient materials. We have been too much in the habit of regarding these, or some of these, as simply physical processes like endosmose and exosmose, forgetting that the structures through which the nutrient materials pass are composed of living protoplasm, which so modifies the physical process as to make it unlike what would happen if the membrane were dead.

Already we are getting some insight into the molecular processes concerned in life. This is well illustrated by the changes in the cells of a secreting gland. Take, for example, the pancreas. The ultimate structure shows a number of cells grouped around a space at the end of a canal, which is the beginning of one of the ducts of the gland. Each cell is a minute spheroidal body having a nucleus and composed of protoplasm. So far as the nucleus is concerned, we may put it aside as it appears to have nothing to do with the secretive activity of the cell, and to be concerned only in its reproductive processes. One side of the cells is bathed in a fluid called lymph, which has transuded from the capillaries in the neighbourhood; the other side is free and projects into the space. Secretion consists in the accumulation of fluid in this space, and as it is formed it is carried away by the ducts of the gland. Now few, if any, of the elements of the secretion exist preformed in the blood; they must then be produced by the activity of the cells of the gland. The cells are nourished by the lymph, and they grow and undergo various remarkable changes that have been observed only during the last two or three years. It has been noticed that in the cells there are periods of rest alternating with periods of activity. During the period of rest the cell grows and increases in size, and this is owing, not so much to increase in the network of the protoplasm, as to an accumulation of material in the meshes of the network. It has further been noticed that as the material in the meshes increases, the network diminishes, indicating a conversion of the substance of the network into the matter in the meshes. Sometimes this matter may be seen as little granules, and the granules collect chiefly at the side of the cell next the lumen of the canal. During active secretion these granules disappear and the cell diminishes in bulk; the living protoplasm relieves itself, as it were, of its hoard of stored-up material; in the act it may still be growing to some extent, but the growth of protoplasm is chiefly during the period of rest. But a further discovery has been made. It has been ascertained that the ferment matter in the pancreatic juice which is its chief chemical characteristic—a substance called tripsin—does not exist in the cells of the gland. The particles in the cells I spoke of are not particles of tripsin, but are particles of a material that readily yields tripsin. This material has been called tripsinogen, or generator of tripsin. The order of events would seem to be, (1) the growth of protoplasm from materials supplied by lymph; (2) the conversion of portions of this protoplasm into tripsinogen; (3) the ejection of the tripsinogen; and (4) its conversion, probably in the very act of ejection into tripsin. Thus we get a glimpse into the processes going on in this wonderful little laboratory. Possibly we see only several of the steps of the process. From the matter in the lymph to the protoplasm of the cell there may be many transient stages, and again from the fully formed protoplasm to the discrete particles of tripsinogen there may be another series of steps. Another view is that the protoplasm by one magical stroke, as it were, converts the material of the lymph into living matter, and then, in a instant, there may be the degradation of a portion of the protoplasm into tripsinogen. Of this we at present know nothing; but the evidence points in the direction I have indicated.

Another illustration of molecular action is found in the study of the changes in muscle when it contracts. Here we have, not secretion, but a change of form,—contraction. The evidence is gradually accumulating in favour of the view that this contraction is due to a sudden change (of the nature of a decomposition) of a contractile matter in the protoplasm of the muscle cell. When a muscle contracts there is the evolution of carbonic acid, the muscle becomes acid, from the formation of a special variety of lactic acid, and there is evidence of other chemical changes. Do these substances come from the protoplasm of the muscle cell directly? There are facts supporting a striking analogy with the changes happening in the secreting cell, namely, that the protoplasm of the muscle cell forms a special contractile matter, and that this contractile matter explodes, or, in other words, is torn to pieces in a molecular sense, when a muscle contracts. The products of the decomposition are ejected; the protoplasm again constructs the contractile substance at the expense of its own material; and the muscle cell is soon ready for another contraction. The energy is set free both as motion and heat, whilst in the case of the secreting cell it appears as heat only.

There is every reason to believe that molecular changes of a similar kind occur in the nervous system. We know next to nothing of the chemical changes happening in nervous tissue, but a study of the nature of the nervous discharges that stimulate muscular fibre to contract, and a review of what is known of the order of events in various kinds of reflex actions, all favour the view that these phenomena depend on molecular disturbances of a chemico-physical kind. When a nerve is irritated, some change is propagated along it to the muscle; this change acts on the matter forming the nerve endings; and the changes in these, in turn, set up the molecular explosions in the contractile stuff of the muscle cell. Again, when a sensory impulse reaches a nerve centre, it may stop there—that is, its energy does not seem to be sufficient to do more than set up changes in the substance of the cell; but in other cases the change in the nerve cell may be rapidly propagated to other groups of nerve cells, and these, in turn, may originate impulses causing muscular contractions. The time occupied in these processes, the occurrence of fatigue, the necessity of repair, all point to the occurrence of molecular changes.

Living matter, then, must exist in many different conditions. The protoplasm of a muscle cell is not the same as that of a secreting cell, and both differ from the protoplasm of a nerve cell. Again, the protoplasm of a contractile cell from a sheep differs from that of a man, and there may be varieties even in individuals of the same species. And yet in all the kinds of protoplasm we have, in a subsidiary way, some of the fundamental characteristics. All kinds of protoplasm have the power of assimilation, and all have the property of irritability. What then we mean by living protoplasm is that state of matter which does not ascend higher in the scale of molecular complexity, but breaks down on stimulation into simpler compounds. It is matter in a state of incessant change and when it is killed it ceases to be protoplasm. According to this view, protoplasm exists only for an instant, or, at all events, for only a brief space of time. The materials we get from a bit of dead muscle, albumen, sugar, fat, saline matters, water, were never alive as such; it is absurd to speak of living albumen; these are matters formed on the death of the protoplasm, or they have been derived from complex bodies that have once been protoplasm, possibly existing in the meshes of the net work at the time of the death of the protoplasm. This view of life also gives some conception of how transient it is. The words of Keats may be appropriately used:

> "Stop and consider! life is but a day;
> A frail dew drop in its perilous way
> From a tree's summit."

These considerations all bear upon our conception of what life really is. Few, if any, physiologists would assert that life is added to matter, a force, an etherial intangible something which eludes our thoughts. Nor is it enough to say that it is a property of protoplasm. Is it not nearer the truth to say that it is a special condition of matter? Physicists now consider the properties of things as expressions of internal movements, and in like manner it seems to me we get a conception of the vital state when we consider it as a mode of motion. The phenomena of life are manifested by matter in a condition of intricate molecular movement, the results of which we see in histological structure and in specific function. Arrest the movements by the removal of water, as in dried seeds and dried infusoria, and all the phenomena of life cease. Stop the movements by cold and the organism becomes dormant, but the molecular machinery is ready to start again when it is raised to a proper temperature. Heat the organism too much and the molecular movements are so altered, or disturbed, or quickened, as to be incompatible with the living state and the machinery may fly to pieces. The properties of different kinds of protoplasm depend, according to this view, not on the properties of the chemical elements or chemical compounds which we can extract from it after it is dead, nor on the play of the ordinary physical forces, but on the particular kinds of molecular motion occurring in the living stuff. Thus life expresses a dynamical state, and may be spoken of as a property of matter in the same way as we use the term to designate heat, elasticity, or electricity. It cannot be called a mode of energy, because we cannot bring it within the great law of conservation of energy. What I contend is that vitality cannot be entirely explained by an interplay of the known modes of energy that we call physical. It is a condition of matter *sui generis*. And may we not hazard the conjecture that it is vain to speculate on the origin of life, just as vain as to inquire how, from the primitive atoms which are believed to construct the universe, the movements of matter we term heat or electricity first originated? It has always appeared to me to be a reasonable hypothesis, apart altogether from the evidence many hold as coming from supernatural sources, that the Creator first started this whirl or intricate dance of molecular motion we now call living matter, and that since that time living matter has come from living matter only.

I have led you to-day into these advanced problems, as showing the path physiology is pursuing, and as an indication to you of the deep interest of the subject. My friend Dr. Limont will, during the session, lay before you many facts which you can afterwards think of in the light of these speculations. You see the high course of study before you. I trust that the session which you have begun will be characterised by efficient teaching, diligent study, and high moral tone. Without these, failure is inevitable—with these, success is certain.

At the close of Professor M'KENDRICK's address, the Gold and Silver Medals gained during the past year were handed to the successful students by Principal M'CALL, who announced that of 118 students examined during the past session by the Board of Examiners appointed by the Royal College of Veterinary Surgeons, 88 students had been successful in passing the examination. (Applause.) He intimated that he had founded a Free-studentship for the son of a deceased or indigent veterinary surgeon, and had made arrangements for a Bursary of £20, or a Gold Medal of that value to the student who obtained the highest aggregate marks in his first and second examinations before the Board of Examiners. (Applause.)

Dr. Marwick said,—Gentlemen,—In compliance with the request which your Principal has just made, I rise to propose a cordial vote of thanks to Professor M'Kendrick for his most interesting Address.

I am too sensible of my inability to speak in adequate terms of this Address to say more in regard to it than to express the hope that we may, erelong, be permitted to have it in print for private perusal and consideration. Its interest, obviously, is not limited to the student of medicine—it appeals to every thoughtful man. In being addressed to you here it recognises and emphasises the fact that the profession to which you are to devote yourselves has much in common with that of the physician and surgeon. We cannot shut our eyes to the fact that in every department of professional life, the preparation which was accepted as sufficient thirty or forty years ago, does not meet the requirements of the present day. In the profession with which I am myself connected, for example, a much higher standard is applied than used to be considered necessary. No law student can be held to satisfy present requirements who confines himself to a superficial acquaintance with his test books, and refers to reputed decisions simply to find what judgments have been given under conditions as nearly as possible similar to those in which he may be called on to advise and act. The real student seeks to grasp principles,—to trace the growth and development of these principles in older and cognate systems of jurisprudence,—to see how these systems have been and are applied in other countries,—and so to raise himself above the antiquated standard of the mere case lawyer. The same observation applies to the study of the profession to which you are to devote yourselves. No man who contemplates the practice of Veterinary Science, as it should be prosecuted, may content himself with the attainments of the practitioner of former times, or the application to ever varying animal ailments of stereotyped methods of treatment. Diseases, moreover, seem to change their type both as regards man and the lower animals, and to the investigation of their causes and remedies the highest intelligence and the most advanced modes of investigation must be directed. We have illustrations of this in the methods by which the treatment of cholera and hydrophobia are being even now investigated. In like manner also, when cattle disease threatened, some years ago, to decimate our herds, the local authorities of our large towns had to call in the aid of the most skilled men who carried into their investigations the highest methods and appliances of science. For similar investigations, and the modes of treatment which may be suggested by them, you and the veterinary surgeons of the future must be prepared. In the knowledge and skill acquired by the study, theoretical and practical, of anatomy, botany, chemistry, and physiology,—in the constant use of the microscope, and the most delicate instruments of physical research you will find the best means of equipping yourselves for your profession, and I believe a pleasure and fascination altogether independent of financial results.

One could not listen to the results of last session's work, as these have just been stated by Principal M'Call, without being satisfied that in this College you have all the advantages of a thorough system of training. May I be permitted to express the hope that you who are now passing through the curriculum may so avail yourselves of your opportunities as to be enabled in after life to elevate the practice of your profession, and to place it in close alliance with that of the physician and surgeon with which it necessarily has so much in common.

Of Dr. M'Kendrick and his claims to our thanks, I do not feel myself at liberty to say more in his presence than that he has laid us all under obligation by his Address here to-day. I feel assured you will very cordially express your sympathy with the vote of thanks which I have had the honour to propose.

The vote was heartily accorded, and a similar compliment to the Chairman, on the motion of Prof. M'Kendrick, brought the proceedings to a close.